Treatment Systems

Tips for Improving Water and Wastewater Treatment ProjeCTS

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This article summarizes tips for improving water and wastewater treatment systems from recent personal professional experience (1 to 10) gained primarily through projects funded by the Asian Development Bank (ADB), U.S. Agency for International Development (USAID), and World Bank/ Food and Agricultural Organization (WB/FAO). By "improving," the author means making such systems more robust, risk adverse, and responsive to regulators, consumers, and other users. The viewpoint is taken from the "hardware, equipment or physical side", and "soft, human resources, or financial side."

Tables A through C summarize the tips in terms of hard, soft, and hard and soft technology sides, respectively. A few examples are discussed throughout. Figures 1 through 3 are applicable photographs taken by the author.

Figure 1 shows a large sand-filtration system that treats 66 million gallons per day (mgd) from Ottoman. It was developed from a natural grotto fresh-water spring during the wet season at Salim Lahoud-Dbaye Water Treatment Plant to supply urban Beirut, Lebanon.

Figure 2 shows the Aqaba (Jordan) Wastewater Treatment Plant completed in the 1980s and upgraded several times. It treats 5.5 mgd of municipal wastewater from metropolitan Aqaba to supply effluent to irrigate golf courses, landscape areas, and medicinal herb fields. It also provides water for cooling water phosphate mining in the Dead Sea, and produces commercial quality compost.

Figure 3 shows construction at pretreatment works for As-Samara (Jordan) Wastewater Treatment Plant. The plant was completed as an advanced modern build-operate-transfer (BOT) plant in 2011 to service more than 3 million people in Amman and Zarqa (40% of Jordan's population). The project began from an initial very large and overloaded wastewater stabilization pond system. The new BOT plant treats 221 mgd first by pretreating metropolitan wastewater in Amman, then transporting the pretreated effluent 35-kilometers (km) horizontal distance, and 440-meter (m) elevation drop to generate electricity en route to the Dead Sea. It produces commercial quality methane and compost, and desalts a portion of its effluent to dilute its saltier effluent to make the mix suitable for crop irrigation.

The author is often asked, "What are the lessons learned in international water resources development?

Several things stand out and are listed here.

1. Just because something can be done, there is no reason to do it. For instance, even though you can build a water treatment plant, first consider if it is prudent to do so.

Figure 1. Sand-filtration system at Salim Lahoud-Dbaye Water Treatment Plant, Beirut, Lebanon.
Photograph by Popkin (Feb. 26, 2011).

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Figure 2. Aqaba Wastewater Treatment Plant, Aqaba, Jordan.
Photograph by B. Popkin (Nov. 30, 2006).

Figure 3. Pretreatment works for As-Samara Wastewater Treatment Plant, Amman, Jordan. Photograph by B. Popkin (Nov. 29, 2006).

2. If a water treatment project should be done, that's not the reason you should build a project. Consider whether or not the host country or other donors should instead build the plant.

3. Most foreign assistance for development infrastructure work fails because it imposes projects on people who can't afford to operate and maintain them as they don't have the human resources, nor the capital or the financial network to keep them running. In fact, in the developing world, "sustainable" usually means another donor will take your place when you leave!

What Works?

For international development, experience shows which donor interventions work well, and which ones do not. In general, what works is as follows:

1. Beneficiary driven and community-based. They will more likely support a water treatment plant.

2. Basic and vocational education, scholarships. Recipients can learn to operate water treatment plants.

3. Agriculture value-chain. Beneficiaries can gain incentive to treat and reuse wastewater.

4. Small-to-medium business loans/grants. Small water supply and treatment plants may produce large sanitation benefits.

5. Eco and historical tourism. Water-based recreation, fishing, bird watching, and of course fish-farming are good water uses

6. Simple healthcare, vaccinations, medicine. Water is a source of life; good water quality is essential to good health.

7. Contracting—avoid errors/omissions. Be sure contracting is wise, especially in large-scale water projects that are best bid as fixed-price, not-to-exceed, rather than time-and-materials for the best value.

8. Management, monitoring, evaluation, and follow-up. It is essential that water volumes, flowrates, and quality are assured to meet or exceed specifications.

9. Indicators, results, and impacts. Impacts are most difficult to address, but good water policies should lead to reduced disease and lost work time from illnesses, increased life expectancy, and ultimately increased discretionary income and wealth.

10. Cultural understanding/sensitivity. This is especially true in countries where long holidays and ceremonies preclude work, so water distribution and treatment plants are likely to fail during these periods.

11. Improved communications. The illusion is that we understand each other. Communication is improved by discussions, visuals, checklists, training,

and routines; be sure to assure water sector operators understand fully what their duties and responsibilities are, and they have the skills and finances to carry them out.

12. Women-based support. Women often are more detailed, multi-tasking, and responsible than men. Experience consistently shows that if women are behind a water issue that will improve sanitation and the health of their families, the activity is more likely to succeed.

What Doesn't Work?

The following list gives approaches that often lead to water project failure.

1. Donor-driven, top-down policies. Imposing water treatment plants will usually fail.

2. Large energy, roads, schools, hospitals, water/wastewater, ports that require specialized labor and management, and sustained capital and operations and maintenance. Water/wastewater systems have special labor and management requirements.

3. Dependency on infrastructure. Without backup systems, water treatment plants often fail.

4. Academics/advanced education. Abstract knowledge does not operate a water treatment plant.

5. Large business loans/grants. In water plants, as in any large venture, the opportunity for financial losses, waste, fraud, abuse, and theft are not uncommon.

6. Complex healthcare systems. If a water treatment system is too complex, it is more likely to fail and adversely impact healthcare.

7. Contracting with errors/omissions. These are often intentional and reflect corruption in the water sector.

8. Mismanagement. Water systems subject to poorly selected staff and management, nepotism, cronyism and political versus technical controls are too common.

9. Bad cultural understanding/sensitivity, communications. It is very likely that in being too polite, sound water management policies are ignored, or not enforced.

10. Arrogance/dumb assumptions. Because someone has a title and job description in the water sector does not necessarily mean the person has the skills, motivation, resources, and finances to do the job.

Hardware, Equipment

This section highlights hardware issues: several inflow-lines, multiple storage and bypass lines, expandable land, redundancy, and opportunities in the water sector.

Several inflow lines. Inflows to water and wastewater treatment systems should have several operational options to accommodate system failures or overloads. Such options should allow for bypassing, storage, and diversion to several alternative treatment trains.

Multiple storage and bypass lines. Once inside the water and wastewater treatment systems, flows should have several operational options to accommodate system failures or overloads. Such options should allow for bypassing, storage, and diversion to several alternative treatment trains.

Expandable treatment plant site. Land is expensive and often competitively priced. Although it is quite possible to piggy-back systems for expansion, having available land set aside for facility expansion is helpful. If land is unavailable and piggy-backing or layering is impractical, it may be possible to build separate treatment trains such as providing inflow filtration and settling en-route to the main treatment facilities.

For example, expansions may be needed for additional parking and machine shop and garage space. However, there may also be the need for new plant space to recover and dry process sludges, manage hazardous materials and wastes, and provide methane generators. Water treatment expansion may be needed for water softening, and wastewater treatment for nitrogen and phosophorus removal. Land is often needed for laydown, bone-yard, and warehouse areas that are best located within, or very close to the facilities.

Redundancy. Even robust systems may fail, or be unavailable because of several reasons such as failure to meet excessive demand, mechanical or electrical failures, flooding, fire, construction, and operational errors, or simply accidents and maintenance. For example, the energy grid may fail to provide power when needed, so back-up power is important. Treatment systems themselves require careful operation and maintenance (O&M), repairs, and upgrades that may make them partially unavailable. Therefore, systems should have back-up redundancies to reduce the risk of operational failure. In addition, a full inventory of spare parts and equipment should be readily available and accessible for emergencies as well as planned O&M.

Opportunities. These include the ability to apply evolving technologies, regulations, and other demands in water and wastewater treatment. Evolving technologies in batching, biofilms, nanotechnology filtration, electromagnetic ionization, methane, or biogas production and recovery, oxidation over aeration, and sludge or biosolids handling for composting may provide treatment opportunities that become important to a facility. Regulations going forward may require removal of arsenic and heavy metals from drinking or process waters, and removal of chlorine disinfectants and nutrients from wastewater streams prior to disposal or reuse. Other demands on water and wastewater systems may be imposed by consumers such as noise and odor control, buffer zones, and water-quality blending to reduce salinity of treated wastewater for irrigation or hardness of drinking water for consumption.

Human Resources or Finances

This section highlights soft issues, which may entail appropriate project selec-

tion and contracting, appropriate staffing, extensive training and refreshers, monitoring and evaluation, and specialty contractors in the water sector.

Appropriate project selection and contracting. Projects should be selected and advanced based on engineering, financial, economic, environmental, social feasibility, and cultural acceptability analysis with consultations with communities, stakeholders and beneficiaries. To be clear, economic analysis focuses on direct and indirect societal benefits and costs, while financial analysis focuses on the availability and cost of capital, O&M, replacements and repairs, emergency responses, and related carrying or running costs. Note that stakeholders are persons within agencies, organizations, and groups who are concerned about or interested in projects and activities while beneficiaries are persons who stand to benefit by projects and activities. Project developers should recognize cultural matters, and pricing. Fixed-price, not-to-exceed contracting is more efficient than cost-plus contracting.

Appropriate staffing. Staff should be selected, appointed, and advanced based on their merit, skills, achievements, and motivations as is done in most Western and industrialized countries. Staff hiring and promotion should not be tied to nepotism, cronyism, demographics, sectarianism, gender, race, religion, political, or social affiliations, as is found in many developing countries.

Extensive training and refreshers. These should include water and wastewater facilities operations and maintenance, emergency actions, planned and emergency repairs, health and safety, monitoring and evaluation, risk assessments, accident assessments, regulatory action assessments, consumer survey assessments, and action drills. Training should be provided by experienced technical and educational professionals with pedagogical training and experience.

Emphasis should be on the IRR (Inspect-Replace-Repair) process and the typical strategic sequence of Inspect, Maintain, Repair or Replace, Test and Operate Sequence. Always check the manufacturer's manual. Training is most effective when it is participatory rather than lectures alone. For example, training in monitoring water facility key performance indicators such as Supervisory Control and Data Acquisition (SCADA) and Human Machine Interface (HMI) artificial intelligence systems, leaks and repairs, and emergency responses are preferred. Should this training not occur, then training drills are appropriate.

Monitoring and evaluation. Routine monitoring and evaluation (M&E) can provide good system feedback to identify potential failures and allow timely corrective action. For example, frost and freezing damage, odor and noise, fire and explosive hazards, equipment stresses and overloads may be identified early for prevention, recovery, and remediation before they are mission critical. M&E performed on key performance indicators can often yield the best operational results, risk management, and down-time avoidance.

Several actions are very helpful in M&E. A good beginning point is to interview staff to identify problem areas. Other worthwhile areas to touch on include: 1. Conducting energy, water pressure audits, water-quality indicators (i.e., drinking water parameters, softness, residual chlorine; sanitary engineering parameters for wastewater effluent) and leak surveys; 2. Reviewing security systems and exception reports and strategies for predictive, preventive, and breakdown maintenance; 3. Mapping age, function, and condition of pipelines and equipment; 4. The water system maintenance records, downtime history, accident and safety reports, and agency notices; 5. Conducting detailed audits, including flows, processes, storage, warehouses, administrative and technical procedures and asset-management, administrative, technical, managerial and financial capacity, and perhaps annual and five-year business plans.

Specialty contractors. It is unlikely that any water and wastewater treatment system can provide all the services needed to keep it operational. Specialty contractors fill this void is several areas, such as: independent energy and water audits, maintenance log reviews for corrective and preventive action, and alarms and safety reviews; electrical, mechanical, hydraulic, instrument, and pump replacements, repairs and upgrades; leak detection and repairs; and hazardous waste management. Commonly effective upgrades are: pumps (high-efficiency, variable-speed, demand-driven motors and pumps), and artificial intelligence and instrumentation systems.

Project Success

For successful long-term performance of water and wastewater systems, the use and upgrade of checklists, manuals, and instructional guides are paramount importance. These should be based on operational and maintenance history as well and experience with accidents, failures, and equipment manufacturers and vendor services experience. They should be carefully reviewed periodically to improve them and be used in training, refreshers, and action planning and drills.

Most importantly, projects should be planned (11-15), developed, and synchronized for the long-term and not piecemeal, lest they become incomplete, or disjointed with a great waste of resources and failed hopes. This institutional issue is especially problematic in developing countries that have no ability to issue bonds and depend very much on donor generosity. In addition, project networks (16) should be planned thoroughly, monitored, and adjusted as needed.

For example, Tripoli, Lebanon, is unfortunately known by donors for partially completed wastewater collection and treatment projects where plants have been built and wait and deteriorate for decades before sewer lines are laid and connected to the plants, if ever.

Another example is the early completion of the wastewater conveyances at Alexandria, Egypt, where the spreading tremendous quantities of wastewater occurred for many years on its public streets. This occurred as the wastewater collection system delivered untreated wastewater to a site for which a plant had not yet been completed because of permitting delays for the offshore effluent discharge line. If a facility cannot sustain

itself through sustainable revenues or donor contributions, it will ultimately fail as many donor-funded water and wastewater treatment plants failed in Afghanistan, Lebanon, and Nepal.

In developing countries, wastewater treatment plants that are orders of magnitude more expensive and have higher energy and chemical demands than routine water supply treatment plants are particularly vulnerable to failure. This is because of the frequent lack of operating, maintenance, emergency and routine repair and replacement capital, and the availability of the human capacity of trained and motivated engineers and technicians needed to operate them. Naturally, the commitment, not merely the involvement, of communities and their stakeholders and beneficiaries are needed for large-scale water and wastewater projects to succeed.

Computerized Systems

The role of computerized and artificial intelligence management, monitoring, alarming and recovery systems such as SCADA, and HMI is important as well. They allow for more systematic and less manual-labor intensive process controls, which benefits efficiency, uniformity, and equipment and labor resource allocation. SCADA is often linked to HMI in industrial processing facilities, including energy, water and wastewater plants.

These tools allow administrators, managers, schedulers, engineers, technicians, and other personnel to monitor, evaluate, operate and maintain complex industrial processes through automation, artificial intelligence, and computer-assisted systems. When broadened to affiliated facilities and services, engineers and technicians can be assured of potentially more varied and interesting work as they may be assigned to a plethora of services in various venues beyond the narrow range of equipment (e.g., O&M). For instance, many counties combine their water sector staff with other work sectors so their technical people may monitor, service, repair, and replace similar equipment for other work sectors such as transportation, solid waste management, education, judicial, and police services.

Examples

Here are examples of successful water projects.

The Ashkelon Seawater Reverse Osmosis Desalination Plant, Israel, was planned to produce more than 87 mgd (http://www.water-technology.net/projects/israel/) (17), and became operational in 2006. It has been upgraded yearly and now provides approximately 13% of Israel's domestic consumer water demand.

The Tampa Bay, Fla., seawater reverse osmosis desalination plant, after several delays and challenges, became fully operational in 2006. It is the largest seawater desalination facility in the United States. The Tampa Bay facility produced an initial 25 mgd of drinking water to help reduce the growing demand on the area's aquifers. The plant provides about 10% of the region's drinking water supply, and may be readily expanded. Part of its operating efficiency is based on its proximity to the Big Bend Power Station.

Some wastewater treatment facilities are land-resource poor so they are multi-tiered. The Yannawa Wastewater Treatment Plant, Central Bangkok, Thailand, serves 500,000 people. Yannawa Wastewater was completed in 1999 and currently treats more than 79 mgd in a four-story, sequencing batch reactor plant ((18 and 19).

Other facilities are retrofitted or built to remove nutrients to meet federal regulations. The new land-intensive expansion for anoxic-aerobic nutrient removal at $217 million, at the Ina Road Wastewater Reclamation Facility in Pima County, Ariz., was upgraded in 2012 to treat 25 mgd, including nutrient removal to protect phantom receiving aquatic life and supply irrigation water. The plant was built in 1997 but has been upgraded several times. Much of its treated effluent is used for landscape and crop irrigation, which reduce local fresh-water demand.

Summary

Tips for improving water and wastewater treatment systems include focusing on hard, soft, and the combination of hard and soft issues. The societal influence of good water and wastewater treatment extends beyond simple pollution control, but touches disease reduction, palatable drinking water, and wastewater reuse to reduce fresh-water demand. Detailed troubleshooting for smooth system operations, preventive and routine maintenance, and learning and sharing lessons from errors and opportunities in training and refreshers play a vital role in improving water and wastewater systems.

The rapid rise of computer-assisted artificial intelligence systems in monitoring and evaluation and automated sensing and actions is remarkable. Its technology represents a quantum jump in water and wastewater facility safety, operations, and cost reduction. As populations expand and regulations increase, more detailed attention must be placed on water and wastewater treatment systems in developed and developing countries. Desalination systems may be the ultimate treatment, especially coupled with electro-magnetic dissolution, nanotechnology, and sand filtration as pretreatments.

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TABLE A
Tips for Improving Water and Wastewater Treatment System Hardware or Equipment

Sector	*Actions*
Inflow-lines for treatment and bypass, multiple storage and bypass lines	Plan, implement, monitor and evaluate, take corrective actions; operate and maintain
Expandable land	Acquire, lease, rent; consider multi-stories
Redundancy of treatment	Plan for at least 60% redundancy; operate and maintain
Opportunities to apply evolving technologies, regulations, and other demands	Anticipate, seek out, pursue

TABLE B
Tips for Improving Water and Wastewater Treatment Systems: Human Resources of Financials

Sector	*Actions*
Appropriate project selection and contracting	Selected and advanced, based on engineering, financial, economic, environmental, and social feasibility and acceptability analysis with consultations with communities, stakeholders and beneficiaries; recognize cultural matters, and fixed-price, not-to-exceed contracting is more efficient than cost-plus contracting
Appropriate staffing	Selected, appointed and advanced based on their merit, skills, not nepotism, cronyism, demographics, sectarianism, gender, race, religion, political or social affiliations, as is true in many developing countries
Extensive training, refreshers	Formal, informal, audits, drills; provided by experienced technical and educational professionals with pedagogical training and experience
Monitoring and evaluation	Feedback, updates and corrective actions
Specialty contractors	Learn from competitors, contractors, vendors, other professionals, trades and crafts, and customers and community members for continuous improvement

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TABLE C
Tips for Improving Water and Wastewater Treatment Systems: Hard and Soft Sides

Sector	*Actions*
Checklists, manuals, and instructional guides	Use and upgrade; train and refresh
Computerized management, monitoring, alarming/ alerting, and recovery systems	Implement and upgrade; train and refresh
Institutional issues: *project interruptus*, willingness-to-pay and sustainable funding and financing	Address fully through willingness and ability to pay surveys and commitments, funding and financing; social marketing and promotion; community commitment and involvement of stakeholders and beneficiaries

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